THE GLASS INDUSTRY

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HAND PRODUCTION OF LIGHTING WARE

At its plant in Morgantown, W. Va., The Beaumont Company manufactures a wide variety of blown and pressed lighting glassware, utilizing time-honored hand methods in combination with up-to-date equipment for mixing, melting, annealing and decorating.

In the pauses between his professional activities in New York and Saratoga, the late Richard Canfield was not averse to taking a little flyer in the business world and, at one time, a glass bottle stopper of the trickier sort engaged his attention, as well as some of the proceeds placed in his keeping by the Goddess of Chance. For the manufacture of this supposedly epoch-making gadget, an old woolen mill in Morgantown, W. Va., was equipped for use as a glass plant in 1905, and the Union Stopper Co. began business. This plant and this company were the forebears of what is now The Beaumont Co., a lively glass-making concern of Morgantown, in which the estate of the aforementioned Mr. Canfield still holds a controlling interest.

But the glass stopper failed to live up to its advance notices and flopped almost immediately, whereupon the facilities of the new plant were given over to the manufacture of tableware in 1906, and P. J. Beaumont joined the company as manager. Mr. Beaumont was not only a capable glass-maker, through long experience at Martins Ferry, Ohio, and Grafton, W. Va., but he also brought with him a customer clientele which was most valuable to the new company. A line of stationers' glassware, such as inkstands, etc., was soon added and, within a couple of years, the manufacture of lighting ware was also started. By 1912 the second Beaumont generation, in the person of son Arthur B., joined the organization and father and son still collaborate in the administration of the company affairs, ably assisted by Treasurer J. L. Edwards.

The present name of the company dates from the year 1918, at which time a bottle plant in nearby Sabraton was purchased and operated as a subsidiary of the main plant in Morgantown. The manufacture of glass at the Sabraton plant was discontinued in 1937, however, and all production activity of the Beaumont Co. is now carried on in the Morgantown plant. At the present time practically the entire output of the plant is lighting glassware, including condensers and reflectors, with a small amount of stationers' glass, ruby vigil cups, and other miscellaneous items. In the lighting category the entire production is private mould work, with a great variety of sizes, shapes, glasses and decorations.

The Beaumont plant is located on the bank of the Monongahela River in the northern section of Morgantown, Fig. 1 being a view of the plant taken on a calm summer afternoon by A. B. Beaumont. The main blowing room can be easily distinguished by the pot-furnace

Fig. 1. Lighting ware plant of The Beaumont Co. on the bank of the Monongahela river in Morgantown, W. Va. Photo courtesy of A. B. Beaumont.

Fig. 2. Weighing and mixing equipment. Batches for a great variety of glasses are made up here. Cullet is handled separately. Fig. 3. Continental burners of the pre-mixing, luminous-flame type used for firing day tanks. Fig. 4. A stage in the production of a large, opal lampshade, showing (l. to r.) ball-maker, gatherer and blower.

stack, together with the concrete blowing-room extension toward the river. The structures toward the right contain the materials storage, mixing room and boiler plant, while the farther buildings incorporate the facilities for annealing, finishing, decorating, packing and shipping, as well as the machine and pattern shops. Offices are on the first floor of the two-story building at the far left.

Lighting glassware, as everyone knows, incorporates almost endless combinations of size, shape and kind of glass, but most of the Beaumont output is in white opal, ivory, crystal or "Ferlux," the latter being a semi-transparent glass of the "moonstone" variety. All of the batch materials, with the exception of sand, are received and stored in packages and include soda ash, nitrate of soda, lime, lead oxide, feldspar, fluorspar, borax, manganese, and other minor and coloring constituents. Sand is received in cars over the B. & O. railroad, which runs alongside the plant, and is stored in a big bin in the mixing building.

Equipment for weighing and mixing the batch materials is shown in Fig. 2. The weighed material is dumped into the power-operated filler of the T. L. Smith Co. mixer which, at the end of the mixing operation, tilts and discharges into a batch cart on the floor at the far side. Cullet is handled separately in an adjoining room, where it is crushed and loaded into similar carts. A large proportion of cullet is used in the Beaumont batches and all cullet is produced in the plant, no foreign cullet being used.

The melting equipment includes one 14-pot furnace and three day tanks. Natural gas is used for fuel, the pot furnace being of the regenerative type and operating on a 20-minute reversing cycle. The pots are handled on a 2-day melting schedule so that seven pots are in use at a given time. Pots have a capacity of about a ton and are furnished by Laclede Christy and Gill Clay Pot Co. Each of the three day tanks has a melting capacity of about two tons and is operated each day. The tanks are 60 in. by 100 in., inside, and are built of Laclede blocks. Each tank is fired by a battery of three burners, built by the Continental Roll & Steel Foundry Co. and shown in Fig. 3. These burners are of the pre-mixing, luminous-flame type, combustion air being furnished by a small motor-operated fan. Pots and tanks are, of course, charged by hand from the batch carts.

The multitudinous activities carried on in the orderly confusion of a hand-factory blowing room are familiar to most glass-makers, but to this writer, at least, they remain a never-ending source of interest and fascination.

Fundamentally, the operations pictured in Figs. 4, 5, 6 and 7 are as old as glass itself, and many an old glass man will look at these with a touch of nostalgia for the days when he, too, handled the blow-pipe, the punty, the shears and the hand-press. Here is found the skill, artistry and team-work that characterized the glass industry for many years and, in comparison, the modern, high-speed, mechanical production methods seem prosaic.

Beaumont production is particularly interesting because of the large size and complicated shape of some of the articles. Figs. 4 and 5 illustrate two stages in the production of a big, rectangular, opal lamp shade with vertical flutes. To the initiated, Fig. 4 indicates immediately that the large amount of glass required by this article (about seven pounds) necessitates two successive gathers from the pot, the first gather being given a spherical shape and partially cooled by the ball-maker seated at the left. The gatherer, at the rear, has completed the second gather on the pipe he holds in his hands and the blower is giving the big bubble of hot glass the final shaping before he mounts his stand for the complicated twirls, swings and puffs that precede the blowing operation in the mould.

In Fig. 5 the preliminary manipulations have been completed and the bubble of hot glass is being lowered into the mould, the top section of which will be closed by the mould boy at the left when the proper moment arrives. This mould is of cast iron and is cooled by air from the swivel pipe at the right, after the blown article has been removed and carried to the lehr by another boy. Fig. 6 shows another piece of blown ware being removed from the mould. In this case the operations are the same, except that the shape is round and without flutes, so it is blown in a paste mould and rotated by the operator during the blowing operation. This mould is cooled by water, the mould being wet when the hot glass is inserted for blowing.

The operation of pressing a rectangular-shaped shade, as furnished with modern kitchen ranges, is illustrated in Fig. 7. In this instance, the gatherer has secured a gob of hot glass from the pot with his punty and has placed it in the mould. The presser is cutting off the gob with the shears and will shove the mould under the press plunger at the left, then bring down the plunger by means of a long side lever on the press. When the glass has been squeezed into all parts of the mould the plunger is allowed to "dwell" for a few moments, until the glass sets, and is then raised. The glass shade then cools for a short time in the mould before it is dumped on the adjacent table and finally carried to the lehr. At the Beaumont Co., all "hot-end" operations are in charge of James T. Haden, factory manager, who can be seen looking things over near the furnace in this picture.

Under the regular operation schedule, there are eleven blow shops and five press shops at work in this blowing room, and there is usually a "warming-in" shop for colored glass at a "glory-hole" near the lehr. Altogether about 110 men and boys are employed in the mixing and blowing rooms, which accounts for some of the apparent bustle and activity in this type of factory. The parade of "carrying-in" boys to the lehr is almost continuous and the view at the charging end of the lehrs in Fig. 8 was made at one of the less-crowded moments. The large piece just being shoved into the lehr is the product of the shop whose activities were recorded in Figs. 4 and 5.

Both of the annealing lehrs are 10 ft. wide and the ware is carried through the tunnels on wire-mesh belts. The one at the left, Fig. 8, was installed by the Amsler-Morton Co. in 1927 and is 68 ft. long. It has brick casing and is of the muffle type. The other lehr is 72 ft. long, and was installed by the Surface Combustion Co. last summer. The S-C lehr is of the open-fired, recirculating type and has an insulated steel casing. As shown in Fig. 9, which is the discharge end of the Surface-Combustion installation, both lehrs handle a very large variety of sizes, shapes and weights of ware.

At the discharge end of the lehrs the annealed ware is placed in crate-like, portable trucks and transported to various points where the finishing operations are accomplished. These are all located in a large space adjacent to the ends of the lehrs and include cracking-off, filing and grinding. The cracking-off machine is provided

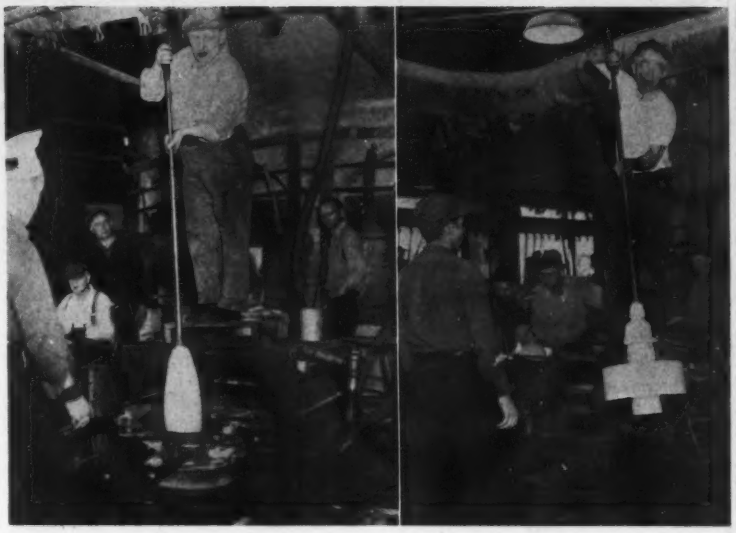


Fig. 5. Left to right: Continuation of the process shown in Fig. 4. Here the blower is lowering the big bubble of hot opal glass into the mould for blowing. Fig. 6. Showing the completion of an exceptionally large item of paste-mould blown ware.

Fig. 7. A press shop at work making rectangular lamp-shades used on kitchen ranges. Factory Manager Haden in the background.

Fig. 8. At the charging end of the annealing lehrs. The large piece entering the lehr is the product of the operations shown in Figs. 4 and 5.

Fig. 9. Discharge end of the 10-ft. Surface-Combustion lehr, showing the great diversity of ware produced at the Beaumont plant.

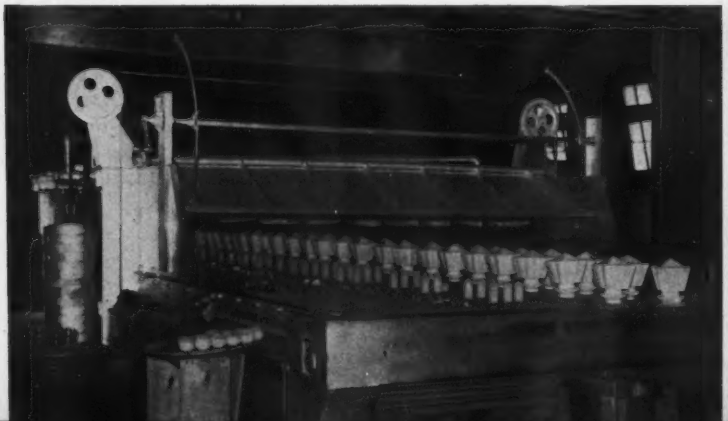


Fig. 10. Hand grinding edges of lamp shades on a cast-iron wheel with water and carborundum.

Fig. 11. Decoration of a large piece of lighting ware by the hand-cutting process.

Fig. 12. Hand decoration of an opal globe. The ware is mounted on a small turntable to facilitate striping.

with the usual adjustable rollers to support the large pieces of round ware and a series of small gas flames to heat the glass at the crack-off point. Rectangular and odd-shaped pieces are made with thin "blow-overs" which are broken off, and the edges of the ware are then roughly finished with hand files. Edges are finally finished by grinding on a cast-iron, rotating plate with carborundum and water abrasive, as shown in Fig. 10. The finished ware, which is to be decorated, then passes on to the decorating department. Undecorated blown ware is packed on the first floor near the finishing department, the pressed ware packing room being located on the floor above.

The work in the decorating department is also greatly diversified, both in the matter of design and materials, the latter including gold, platinum, ceramic colors and enamels. Some wheel cutting and etching is also done, as shown in Fig. 11. On account of the wide variation in color, size and shape of ware, a great deal of the color decorating is done by hand and a couple of these operations are shown in the accompanying illustrations. In Fig. 12 the operator is putting horizontal black stripes on an opal globe, the work being held on a small turntable. This piece also has a series of rectangular panels on which the designs are placed by the transfer process.

The Beaumont ivory ware is particularly attractive in appearance and some lamp shades of this material are shown in process of decoration in Fig. 13. The shades have already been striped by hand and this young expert is putting on the colorful little flowers and sprays of green leaves that decorate the side panels. Another popular and pleasing type of lighting ware produced by Beaumont is evolved by enameling a portion of a crystal glass piece. The white enamel is applied with a spray gun, as shown in Fig. 14, this particular item being a

Fig. 13. Free-hand decoration of ivory lamp shades.

Fig. 14. Spray-enameling of special lighting ware with piece mounted on a small turntable in the booth. Enameled ware in the foreground.

graceful lamp enclosure with a transparent, diffusing bottom and enameled sides and top. The enameling process is a fussy job and success is attained only through careful attention to such factors as cleanness of glass, thickness and uniformity of coating, the enameling material and the firing. Vitro Mfg. Co. furnishes this enamel and other ceramic colors are supplied by many of the leading manufacturers, including Vitro, Drakenfeld, Hommel, and Ceramic Color & Chemical.

From 15 to 20 per cent of the total Beaumont output is of the decorated variety and all of this production is handled by a 5-ft. decorating lehr. This lehr was recently rebuilt by the Surface Combustion Co. and modernized by the incorporation of radiant tubes. Four M-shaped tubes are fired with natural gas. A continuous wire-mesh belt transports the ware through the lehr tunnel.

As stated previously, all Beaumont lighting ware is produced from private moulds exclusively, so the well-equipped machine shop is largely engaged in the cleaning, repairing and maintenance of moulds, with some plant maintenance work.

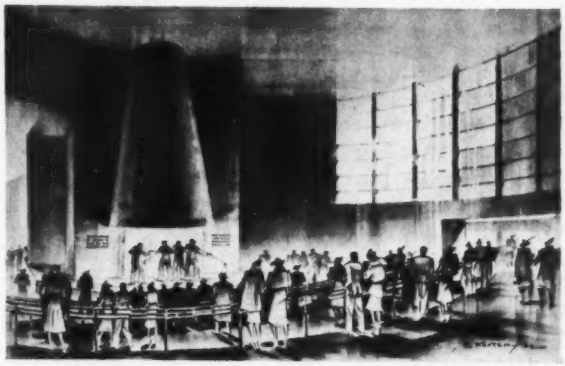
The daily melting capacity of about 12 or 13 tons at the Beaumont plant is, of course, not very impressive in comparison with some other modern glass production units, but the wide diversity of the product is notable. Condensers and reflectors range up to 13 lb. in weight and are sandblasted ready for polishing; pressed items run up to 8 or 9 lbs. per piece; and the blown ware varies in weight from a few ounces up to 6 or 7 lbs. Altogether, the plant offers an outstanding example of how time-honored hand methods can be combined with up-to-date equipment for mixing, firing, annealing and decorating, to produce efficiently a diversified line of specialized glassware.

TOPIC FOR A. C. S. GENERAL SESSION

At the 41st annual meeting of the American Ceramic Society in Chicago, the week of April 16th, Dr. George A. Bole has suggested and consented to lead a symposium on "Importance of Thermal History on Clayware, Glasses, Glazes and Enamels." Dr. F. H. Norton will lead a symposium on "Glaze and Enamel Properties." Both Dr. Bole and Dr. Norton will welcome suggestions or offers of cooperation from the membership.

MAKING GLASS WHILE YOU WATCH

This artist's sketch visualizes the interior of the Glass Center rotunda at the New York World's Fair, 1939, during a demonstration of the actual making of glass. A molten glass furnace will be constructed in an amphitheatre where visitors may watch master glass blowers at work. The entire process, from the time the artisan attaches a mass of molten glass taken from the furnace, through the stages of forming the object by blowing the glass into a bulb, re-heating, shearing, and actual shaping into the appearance of a finished product.



The Glass Center, built primarily of glass, will house the exhibits of Corning Glass Works, Owens-Illinois Glass Co., and Pittsburgh Plate Glass Co. It will be located on the Avenue of Pioneers within the shadow of the Fair's theme of a trylon and a perisphere. More than 20,000 sq. ft. of glass block, plate glass and structural glass will go into the construction of this unique building.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING DECEMBER

Glass Containers: Production of glass containers during the month of December, 1938, was 3,514,537 gross, bringing the 1938 total to 43,097,169 gross. Shipments during December were 3,042,414 gross, bringing the 1938 total to 43,366,252 gross.

Plate Glass: The production of polished plate glass by member companies of the Plate Glass Manufacturers of America during December, 1938, was 12,691,262 sq. ft., as compared to 12,883,448 sq. ft. produced in the preceding month, November, and 8,920,809 sq. ft. produced in December, 1937. This makes a total of 85,725,919 sq. ft. produced during 1938, as compared to 192,592,600 sq. ft. produced in 1937.

Window Glass: During December, 1938, the production of window glass was 1,003,150 boxes, which represents 61.7 per cent of industry capacity. As compared with this, December, 1937, production was 953,964 boxes, representing 58.7 per cent of industry capacity.

INVESTIGATION OF THE GLASS CONTAINER INDUSTRY BY THE U. S. DEPARTMENT OF JUSTICE

By F. W. PRESTON

The views given below are Dr. Preston's own; the account given below is an interpretation of the proceedings as he saw them, not strictly a reporter's history of the proceedings. It is hoped that his method of treating it, while strictly fair, will be more intelligible to our readers than a mere digest could be.—The Editor.

For perhaps a decade now, there has been, not only in the United States but in England and other countries, a good deal of searching of heart, as to whether the patent system was working out entirely as originally expected. The principal question has been, in England for instance, whether a poor man could afford to own a patent; whether in fact, anything short of a wealthy corporation could afford to own a patent. It has been said, for instance, that "a patent is merely an engraved invitation to a lawsuit;" in less pathetic and more vigorous terms, it has been asserted "No patent is worth anything till it has been litigated." This means, if true, that no one can afford to own a patent who cannot afford costly litigation; it requires the owner to be wealthy. It also means, if true, that no one can afford to own a patent who is not prepared to give not only money, but a lot of time, to litigation. It means in practice that only specialists in patents and patent law can afford to own valuable patents. We say "valuable" patents because anyone can afford to own valueless patents if he can afford to take them out in the first instance.

On the basis of some of the foregoing arguments, Mr. W. R. Levis, President of the Owens Illinois Glass Co., contended before the Temporary National Economic Committee, at its hearings that were intended to "investigate" the glass container industry, that it had been his policy to get out of the patenting and patent holding business, and to concentrate his efforts and those of his company, on the business of making bottles and selling them. Mr. Harrison McNash, President of the Hazel Atlas Glass Co., also testified that he and his company did not care to devote themselves to patenting and patent holding: "We are bottle manufacturers."

Going back now to the essence of the idea of a patent, it may be said that, while the Department of Justice, at the hearing, kept contending that a patent was simply a "grant" from the Government, that is not entirely true. It is more nearly a contract. The inventor gives to the Government a disclosure, a "full and complete" disclosure, of his invention, to the end that those skilled in the art may, after a while, practice and use his invention freely. In return the Government gives to the investor the right, or at any rate a *prima facie* right, to exclude any and all persons from practicing his invention during a limited time—in the United States seventeen years.

An inventor is not obliged to disclose his invention. He can keep it secret if he wants. He can practice it in secrecy if he wants, or he can take his secret to the grave with him. But to induce him to disclose it, so that after a short time it may be public property, the Government gives him the right to patent it. He then does not need to practice secrecy; he can use his invention openly, and (theoretically) the Government will stand behind him to protect him in his monopoly for seventeen years.

That is the idea, the basic contract; but the Government never has fulfilled its end of the contract. The Government grants the monopoly, but does not enforce it. The Government does not sue infringers, or initiate any action against them. The owner of the patent must sue them, and normally must sue in an ordinary court that does not understand what the patent is about. The Government that grants his monopoly, does not guarantee it. The courts can decide whether the grant is valid or not, as well as whether there has been infringement or not. This is really as it should be, for the court is likely to be presented with fuller evidence in a suit, than the patent office gets in a patent application. But none the less, it puts an almost impossible burden upon the patent owner unless he is wealthy.

It is most probable that the framers of the original patent laws expected the inventions to be practiced by individuals or small organizations; they hardly envisaged the growth of corporations of modern size, making bottles or any other commodity. In the United States, a corporation cannot apply for a patent; the patent can issue only to the individual or individuals who actually invented the invention. In England, the inventor proper can combine with his company and apply jointly with them, for his patent. However, in both countries, the inventor can sell his patent; it is a negotiable or saleable right; and in modern times he usually transfers it to his own company or to some other company which is interested in acquiring it. This company may own many scores or hundreds of such patents. Thus in the course of the Washington hearings, Hartford-Empire testified that it owned some 700 patents, and Owens that it owned some 500.

Now both of these companies also testified that many of these patents were of little value. If pressed, they might have agreed that most of them were substantially valueless. What is the point of taking out valueless patents?

Some years ago the present writer was informed on credible authority, that some large corporations outside the glass field proper, like Westinghouse for instance, figured that out of 50 patents, 49 would never pay for themselves. The remaining patent, however, would pay for them all.

At Washington it was testified by Hartford-Empire, that you could rarely, perhaps never, tell at the time of application for a patent whether it was going to be a good one or not. It had to undergo a great deal of development, of trial, of experience, of seasoning (they might have added, in view of what I have said above, probably of litigation also) before it became apparent whether it would be a profitable patent or not.

It is thus clear that one must play for percentages, just as the Fuller Brush man does. If he knocks at enough doors, he will sell a brush, provided he does not knock on the doors of empty houses. In the same way, if an inventor takes out enough patents, he will ultimately get a good one, provided he is not working over an empty field of no industrial interest. The preamble to his patent application requires him to state that his invention is *useful*, but in practice the mortality is very high and most patents prove to be useless. This again makes it difficult for any but the wealthy to go seriously into the business of taking out patents. The percentages are against the poor. But the reader should not forget that the percentage is there; and therefore, by definition, a small percentage of those people who own only an odd patent or two, will own lucky patents, and make money on them.

This results in a great deal more complexity to the patent system than its founders probably envisaged. It results first, in the forming of groups of patentees like Hartford-Empire, where by collaboration of a group of engineers, the "percentage" is made to ensure the living of the whole group. It results also in the taking out of patents in great numbers, as a precaution or insurance, a process of "fence building," which came in for a lot of comment, mostly confused, and usually uncomplimentary, at Washington. For since it is so uncertain at the time of patent application, which of many applications may ultimately be valuable, it is morally certain that a patenting group (or for that matter an individual like the writer) will not actually bring to commercial perfection and utility all of his inventions. The average inventor is as full of ideas as a bird is of feathers, and most of his ideas are legally patentable; but his life is too short for him to develop all his ideas, and the changing structure and needs of society would necessarily kill some of his ideas as commercial projects; and again, as Hartford testified, of two or three perfectly feasible and practicable inventions, there is not really room for all to survive. We choose the best, or what we believe best, and let the rest die. In this respect, our practice differs no whit from the proper management of a forest. We plant many seedlings, and some die; of those that grow into sturdy saplings, there is room only for one in four perhaps, and the rest must be cut out, though they be perfectly good and promising trees. On this basis, the Hartford air-feeder was weeded out in favor of the plunger feeder, though either will work.

This rather simple matter seemed to disturb the Investigating Committee a good deal; they seemed fearful that the public was being deprived of something useful, that all inventions ought to be developed, and all patents "worked," or brought to commercial exploitation. In practice, inventions and patents are just like asters or petunias. You always plant a lot more seeds than you need as grown plants; then you will have enough.

The Department of Justice was supposed to be investigating the industry in a search for monopolistic practices. Since a patent is a monopoly, for a limited period of years, Mr. Arnold, Assistant Attorney General, made no bones of the fact that he didn't like patents at all, and tried to persuade Mr. Levis to say that he would be better off without any patents or patent situations. Mr. Arnold also tried to persuade Mr. Goodwin Smith of Hartford to admit that he (Mr. Smith) was less well qualified than the Government to say who shall be given a license under any particular patent. For some reason Mr. Smith could not agree. Possibly he felt that a man's right to full membership in the glass industry should depend to some extent on his having served an apprenticeship to it, and not on his being a deserving Democrat.

The idea underlying the patent law is that the patent is a monopoly, unqualified and unlimited except in one respect, viz., that it has a time limit, and then the monopoly ceases abruptly and completely. In America, it is a well understood principle, as Mr. Levis took occasion to point out, that a patent does not confer on its owner the right to use his invention, but the right to exclude others from using it, for a time at least. The law does not require him to *practice* his invention; that would be impracticable; all he is required to do is to *disclose* it.

Abroad this is not always so. It is somewhat generally recognized that public interest lies in the exploitation of an invention, not in its disclosure. Thus in some countries, in fact in most countries, there is a system of "renewal fees." These often work considerable hardship, but the idea is this: after a few years from the time a patent is granted, the inventor ought either to be working the invention or to have arrived at the conclusion that it isn't worth working. If he is working it, he can afford to pay an annual fee to keep his patent valid until the maturity date of his monopoly. If on the other hand he has concluded it is not worth working, he ought to abandon it and not clutter up the field of industrial activity with dead trees lying all over the ground. The idea sounds logical, but it over-simplifies the problem. It would take too long to go into it here, and the matter did not come up in Washington; but it may be said that no country calling for renewal fees has made the inventive progress of America, nor has its industrial system developed comparably; so in all probability the dead patents are not normally a serious hindrance to industrial progress.

Again in some foreign countries there are systems of compulsory licensing; so that if an invention is not being worked, or not being worked adequately, the Government may require the owner to grant a license to any applicant, and if the applicant and owner cannot agree on terms, then the Government will settle the terms. In practice this also results in complications, and does not seem to have produced any phenomenal results. The simple American system of unqualified monopoly for a limited period has not worked badly; in fact it seems to have worked very well. For, in general, self-interest will induce the working of any patent capable of being worked advantageously, far better than any bureaucratic intervention can. There is, theoretically, the possibility under the American law, of taking out patents for the express purpose of preventing the development of inventions. Such a possibility was indicated in a memorandum read into the record at the hearings. That possibility, however, is one that has always been recognized; there is nothing new about it, and foreign patent laws indicate it has agitated foreign legislators just as it seemed to agitate the Temporary National Economic Committee at Washington. We believe the agitation un-

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EFFECT OF SUDETENLAND ANNEXATION ON GERMAN GLASS INDUSTRY*

By C. M. GERRITY,

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About 80 per cent of the Czechoslovak glass industry is situated in that part of the country which has now been returned to Germany. By the acquisition of the highly developed Sudeten glassworks, the German glass industry is confronted with the important problem of adjusting and reconstructing the entire glass industry on a national basis.

The position of the Czechoslovak glassware industry in the world market has depended not only on the high standard and variety of its hollow glassware, but also upon the important development during the past ten years of an export trade in machine-made flat and bottle glass. So important was the Czechoslovak glass industry that in the export trade it ranked in second place after Belgium. Approximately four-fifths of the entire production was exported.

The hollow glass industry is widely scattered over the Sudeten District and it has not yet been possible to make an accurate survey of production and capacity output for this branch of the industry. The number of hollow glass factories in the Sudeten District is said to have declined during the past ten years, or to have been previously overestimated, and that the present reported number of 100 embraces all of the hollow glass factories in the whole of Czechoslovakia, including numerous small plants. In any case there are 42 establishments in the Sudeten District operating 64 plants, of which 13 produce glass rods and 5 produce flint and colored bottle glass. The remainder manufacture glasses for such products as lighting fixtures, incandescent lamp globes, etc. The largest of such factories is the Glasfabriken und Raffinerien Josef Inwald A.G. with plants in Teplitz, Podebrad and Deutsch-Schützendorf.

In 1935 the hollow glass industry was in a difficult situation brought about chiefly by declining exports. The government then intervened and in 1936 the investment of capital in new factories was forbidden and compulsory measures for the formation of a glass syndicate were introduced. During 1936 a sales and price regulation grew out of the loose agreements among the hollow glass manufacturers. According to the official cartel records, not less than 37 glass cartels were registered which regulated chiefly sales and prices, while about one-half dozen of them also regulated production. The producers of white hollow glass are represented by the Data G.m.b.H. and all other hollow glass manufacturers (except green glass bottle producers) by the Omnia G.m.b.H.

More than two-thirds of the workers in the Sudeten District glass industry, mostly home workers, are employed in the Gablonz section where the famous Gablonz crystal glassware is produced. The large plants in Teplitz employ but one-sixth of the glass workers. It should be stated, however, that less than one-half of the total number of workers are engaged in the production of glass, the larger number being employed in the processing of the manufactured product, such as painting, engraving, cutting, etc.

In contrast to the widely scattered hollow glass industry with its numerous small plants, the production of machine-made flat and bottle glassware in the Sudeten District is concentrated in only a few concerns which have close relations with the large German, Belgian and French glass producers and whose sales on the world markets have always been regulated by international conventions. While this fact will facilitate to some extent the incorporation and also control of the plants of the Sudeten District, the annexation of this territory means enlarged production capacity for greater Germany which obviously will impel the industry to make internal adjustments and revise its export policy.

The machine-made bottle and flat glass industry of Czechoslovakia is centered in the Aussig and Teplitz districts, the larger companies having their factories in the Teplitz area. The largest factory is the Mühlig-Union Glasindustrie A.G. located in Settenz near Teplitz. The Czechoslovak producers of machine-made bottle glassware work under patents held by the European Bottle Combine. Of the thirteen plants of the important German concern A.G. für Glasindustrie, formerly Friedrich Siemens, two are located in the Sudeten District and have always worked hand in hand with the other large bottle factory, the Mühlig-Union. The third member of the Czechoslovak combine is Flaschenfabriken Fischmann Söhne and their representative in the European Combine is the Böhmische Union Bank which was selected as the control office in 1935 when the situation in the bottle and glass industry of Czechoslovakia became critical. The Böhmische Union Bank, it is stated, has since 1936 been controlled by the Prudential Assurance Ltd., London and certain foreign banks.

Although the annual output capacity of these three factories is 141 million bottles, only 60 per cent of capacity was turned out in 1937. Of 85 million bottles produced that year, 26 million were consumed in Czechoslovakia and half of that quantity was sold in the Sudeten district. It is therefore pointed out that should the Czechoslovak market remain open it would offer but limited sales possibilities to Sudeten bottle manufacturers. Mühlig-Union and Fischmann produce hollow and plate glass as well as bottles. Apart from these two concerns the only others of importance are the Erste Böhmische Glasindustrie A.G. at Bleistadt and the Tafelglasfabriken der Montan und Industrialwerke, formerly Joh. David Starck (administrator of the industrial interests of the Petschek family).

The four Sudeten window glass factories use Fourcault machinery entirely. (*Continued on page* 70)

*Reported through the courtesy of H. B. McCoy, Chief, Specialties Division, U. S. Bureau of Foreign and Domestic Commerce.

AN ATTEMPT TO CORRELATE SOME TENSILE STRENGTH MEASUREMENTS ON GLASS: II

By JAMES BAILEY
Hartford Empire Co.

This is the second instalment of Mr. Bailey's paper, which began in THE GLASS INDUSTRY *for January. Two chapters follow concluding the discussion in the April number.—The Editor.*

The Choice of a Support

Since the small diameter rods have so much greater unit strength, it might be supposed that a greater weight could be sustained by an equal weight of small diameter rods than by one large diameter rod. For example, the average strength of a 1/8" diameter rod 2" long is 9,400 lbs./sq. in., whereas the strength of a 3/8" diameter rod 2" long is 8,330 lbs./sq. in. The first impulse would be to use nine 1/8" diameter rods instead of the single 3/8" rod. This would be an error. The problem is one dealing with a group of nine rods, the weakest one of which will determine the strength. The strength should be found from the Area Function which would be the same as that for a 1/8" rod 18" long. The combined area is 7.06 square inch, N = 49.1 and the average strength of such a combination of rods would be approximately 7,500 lbs. The single rod is much stronger.

The Flaw Pattern and the Character of Stress

Up to this point the effect of the flaw pattern on the strength of specimens tested in cross bending and in direct tension has been discussed. In both of these cases the major tensile forces were parallel to the axis of the test pieces and hence may be considered as having only one direction.

If the test piece were a thin hollow sphere or a bottle, and the stress were produced by internal pressure, the stresses set up would have components in all directions and would be two-dimensional.

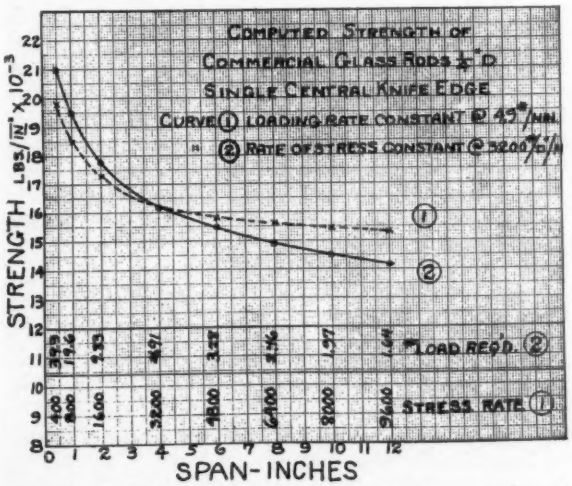


Fig. 5. Dependence of strength on details of apparatus and test procedure.

A three-dimensional stress would be one in which the specimen is completely surrounded by a hydrostatic pressure, which pressure may be either negative, and cause dilation in all directions, or positive, and cause the specimen to be compressed in all directions.

In practice a test piece is affected by complicated stresses, and all types of stress are usually present in some degree. However, the three-dimensional stresses are in most cases too complicated to treat and it is customary to discuss the stresses in only those test pieces which have all of the principal stresses in one plane, the stresses in the third direction being so small that they exert no major influence upon the result. In the following discussion the effect of the flaw pattern upon the strength of three generalized types of specimens will be considered, namely:

1. rods tested in direct tension and rods tested transversely.
2. a spherical shell stressed by internal pressure.
3. a cylinder closed at both ends stressed by internal pressure.

Definition of the Flaw Pattern

Throughout the discussion the flaw pattern has been referred to as if it were a definite thing. Unfortunately, the flaws which cause breakage usually cannot be seen. They may be a plane of weakness in the silica lattice of the glass, or a system of surface irregularities, or a system of minute scratches.

In order to get a mental picture of the flaws, it will be assumed that the most weakening flaw is the largest, and that the weakening effect may be defined in terms of

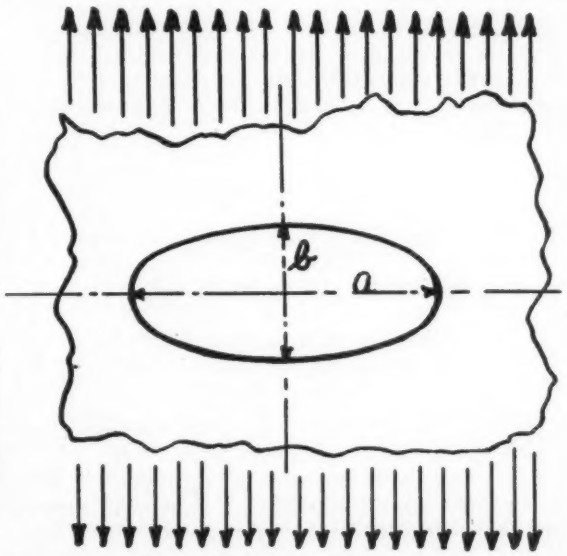


Fig. 6. An elliptical hole in a plate stressed in tension across the long axis.

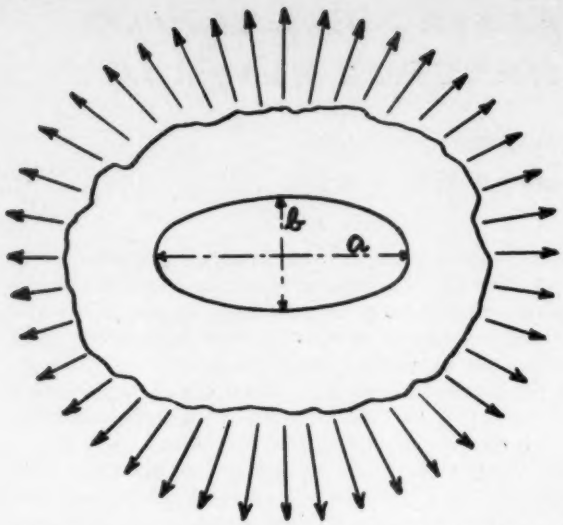


Fig. 7. An elliptical hole in a plate stressed in all around tension.

length. Since we shall not attempt to deal with the actual size of the flaws, this assumption will not invalidate the result. If these flaws have been produced by the laws of chance, both their size and their orientation with respect to the direction of stress will be random functions.

We may, therefore, define a flaw as a discontinuity in the structure which controls the strength of the whole and which affects the strength in proportion to its size and to its orientation with respect to the direction of stress.

Flaws of this type produce stress concentrations in the material adjacent to the ends of the flaw of a type similar to those in a stressed plate having an elliptical hole through it.

The Effect of an Elliptical Hole in a Stressed Plate

The effect of an elliptical hole upon the stresses in a plate has been worked out both mathematically and by photo-elastic methods.[8] Coker and Filon give for this case, when the applied unit tension is across the major axis (Fig. 6):

$$Tm = T\left(1 + \frac{2a}{b}\right)$$

and when the applied tension is across the minor axis:

$$Tm = T\left(1 + \frac{2b}{z}\right), \text{ where}$$

Tm is the maximum stress due to T
a is the length of the major axis
b is the length of the minor axis

In these formulae it should be noted that when b approaches zero, Tm approaches ∞ when the applied tension is across the a axis, and Tm approaches T when the applied tension is parallel to the a axis. This means that with a one-direction stress the effect of a crack upon the strength will vary from a maximum, when the lines of force are perpendicular to it, to zero when the crack lies parallel to the lines of force.

In the case of "all around" tension, such as a drum head tension or an element of a spherical shell under internal hydrostatic pressure, Coker and Filon give

$$Tm = 2\left(T\frac{a}{b}\right)$$

It follows that:

$$\frac{\text{Tm (all around tension)}}{\text{Tm (tension across a axis)}} = \frac{2T\frac{a}{b}}{\frac{T(1+2a)}{b}} = \frac{2a}{b+2a}$$

When b becomes very small the ratio approaches 1 as a limit. The effect of a crack of equal size is therefore the same in both cases.

The Crack and One-Directional Stresses

When the crack lies at an angle ϕ to the line of tension the problem becomes more complicated.[9] The stress measured by photo-elastic methods for an angle of $\phi = 49°$ between the a axis and the direction of tension was found to be 3.43 times the mean tension. When the major axis lies across the line of pull the maximum tensile stress for the same elliptical hole was 4 times the mean tension.[10] Rotating the elliptical hole 41 degrees reduced the maximum strength in almost the exact ratio as the reduction of the projected length on a line at right angles to the stress.

However, in view of the fact that the analytical methods give infinite stresses when the cracks have zero width, it was deemed advisable to determine experimentally the approximate effect of the angle of the crack.

This was done by cutting strips of paper about ¾" wide and 8" long. Two parallel lines ⅛" apart were lightly ruled down the center of the strip and a series of cuts was made between the lines by means of a sharp thin knife. These cuts were placed lengthwise about ¾" apart. A large series of angles was used. Each paper contained one cut at right angles to its length.

Tension was then applied until the paper broke. A slightly greater tendency for the paper to break by propagating the right angle cut was found, but this tendency was so slight that a 5 or 10 per cent greater projected length on any diagonal cut would control the breakage. While these experiments were crude and made on paper, which is entirely different from glass, owing to its fibrous nature, it is believed that they demonstrate that the effect of a cut in reducing the strength is approximately proportional to its projected length.

The Flaw and the Direction of Stress

The effect of rotating a flaw with respect to the direction of stress may be more easily comprehended by finding the component of the stresses acting across the flaw after the method of Mohr.[11]

Letting P equal the major stress and Q the minor stress, we have, for the three cases:

[8] Coker, E. G., and Filon, L. N. G., *A Treatise on Photo-elasticity.* (Cambridge, 1931), Cambridge Press, pp. 532-554.

[9] Coker and Filon, *op. cit.*, pp. 551, 552.

[10] Coker and Filon, p. 533.

A, the rod in tension or bending $P = 1, Q = 0$
B, a cylinder under internal pressure, $P = 1, Q = \frac{1}{2}$
C, a sphere under internal pressure $P = 1, Q = 1$

If the stresses found are plotted on a radial line making the angle ϕ with the P axis, Fig. 9[12] will result: Here the distance from the point $Q = 0$ to the lines, A, B and C shows the relative magnitude of the stress in the direction shown. If all the stress components are averaged, the result for $P = 1$ will be:

Average stress for $A = .633$; $B = .774$; $C = 1.00$. The relative average strength, making A equal to unity, would be: Relative strength of $A = 1.00$; $B = .817$; $C = .633$.

These are the relative strengths that would be expected if the specimen tested contained one flaw subject to the conditions outlined. Notwithstanding the fact that every flaw in the system would have a similar effect upon the strength, these ratios cannot be transformed into units of N (Fig. 7) nor can they be used as strength modifiers for the corresponding stress systems. It must be remembered that the stress in a specimen during testing is either continually increased or increased by increments and that the weakest point determines the strength of the whole. If the area under stress were so large that one of the largest flaws was certain to lie across the stress direction in the A system then the strength of the A would be found by test to be the same as that of the system C. If the area were so small that the largest flaws occurred only occasionally so that their orientation was as important as their occurrence, then the factors would apply about as derived. The only safe way to locate the connection between the factors and N (Fig. 4) would be by actually testing samples in the three ways, but in view of the small size of the unit area in the rods it seems probable that the corresponding area function N would be approximately that corresponding to the reduction of strength indicated by the factors, as in Table VIII.

TABLE VIII. EFFECT OF STRESS SYSTEM ON AREA FUNCTION.

Stress system	A	B	C
Principal stress P	1	1	1
Perpendicular Stress Q	0	½	1
Average Stress 0° to 90°	.633	.774	1.00
Relative strength	1.000	.817	.63
Strength of Run G: lbs./sq. in.	11,350	9,270	7,150
Corresponding N (Fig. 7)	1	6	84

This investigation is interesting from a practical standpoint in that it shows: (a) the weakness usually found in pressure containers cannot be directly ascribed to the effect of the two-dimensional stresses on the flaws; (b) a considerably larger factor of safety is required, on purely theoretical grounds, for pressure containers than for pieces stressed in one direction.

That the bursting pressure of bottles is considerably less than would be expected even when the area function and combined stress is considered is shown from the following example. The data are taken from Longmuir and Turner.[13] The rate of pressure increase was 15 lbs. per square inch in 2 seconds, equivalent to 450 lbs. per square inch per minute. The various average dimensions were, in inches: wall thickness 0.161, inside

[11]Coker and Filon, *op. cit.*, pp. 120-124.
[12]Ibid, pp. 120-124.

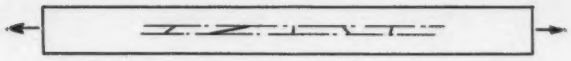


Fig. 8. Paper test piece used to study the effect of flaw orientation on strength.

diameter 3.41, outside diameter 3.73. From the shape it was estimated that the maximum stress was fairly well distributed over the central 1½" of length, and, bearing in mind that experience has shown that rupturing starts in most bottles on the outer surface only, the

Stressed area $= \pi \times 3.73'' \times 1\frac{1}{2}'' = 17.6$ sq. in.
$N = 17.6 \div .1438 \times 6$ (stress type B) $= 735$
Expected strength Fig. 7 $= 5{,}900$

$$\text{Rate of stressing} = \frac{450 \times 3.41}{2 \times .161} = 4{,}770 \text{ lbs./sq. in./min.}$$

Correcting the strength for rate of stressing to give 3,200 lbs./sq. in./min. raises the Run G strength to

$$5{,}900 \times \frac{7{,}250}{7{,}020} = 6{,}100$$

The bursting pressure should be:

$$\frac{6{,}100 \times .161 \times 2}{3.41} = 578 \text{ lbs./sq. in.}$$

The actual bursting pressure was 388 lbs. at 15°C and 343 lbs. at 25°C, the average of which is only 65 per cent of the strength that might be expected from glass having a "Run G" flaw pattern.

Evidently the flaws in these bottles were much more damaging to the strength than were those in the "Run G" rods.

It might be added that most bursting pressure tests

[13]Longmuir, B., and Turner, W. E. S., "The Influence of Temperature on the Bursting Pressure of Bottles," *Jnl. Soc. Glass Tech.* (1934), XVIII, Trans. p. 253.

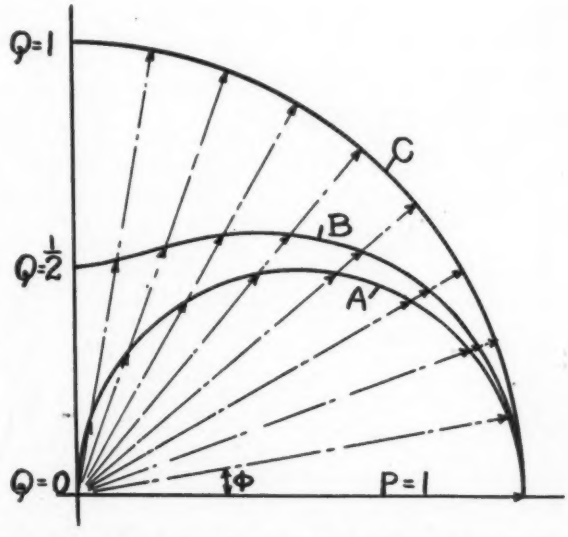


Fig. 9. Diagram showing the effect of flaw orientation in a two directional stress system. One direction tension, line A. Two direction tension under internal pressure as in a cylinder, line B. Two direction tension under internal pressure as in a sphere, line C.

of bottles of this size give average strengths corresponding to pressures between 300 and 450 lbs./sq. in., and a short perusal of the literature will disclose that in most cases the figures for the rate of increase of pressure and the physical dimensions of the bottles are both lacking, so that the data cannot be used to compute either the rate of stressing or the stress, without which the data are essentially useless for engineering purposes.

Evidence of Orientation of Flaws

It is generally conceded that all of the flaw structure resulting in weakness consists of scratches, pit irregularities and other surface defects. This concept is supported by the fact that surface treatment such as acid polishing greatly increases the strength, and by the fact that intentionally made surface scratches will reduce the strength to a small fraction of its original value.

On the other hand, very obvious surface scratches, such as those produced by fine grinding, do not result in a strength reduction much below that found in specimens which appear to be flawless. Treatment such as fire-polishing, which should theoretically result in a perfect surface, does not increase the strength to anything like its theoretical value, nor can a large piece of glass be made to approach the strength of glass found in small fibers.

The theoretical strength of glass has been variously computed at from 2,000,000 to 14,000,000 lbs./sq. in. Strengths well above 1,000,000 lbs./sq. in. have been measured, using very fine commercially produced "glass wool" fibers. A. A. Griffith[14] obtained strengths of the order of 500,000 lbs./sq. in. when the diameter was of the order of 0.00015 inch. Such strengths seem unreasonable when compared with the strength of bottles.

Fine fibers have negligible mass and therefore do not suffer from impact. Moreover, they are exceedingly flexible, and it is difficult to scratch one with another. Bottles, being large and heavy, may be easily injured in both of these ways. However, the injury which an article can withstand without serious decrease of strength should bear some relation to its size, and it seems exceedingly unlikely that virtual freedom from mechanical injury can be advanced as a valid reason for the abnormal strength of very fine fibers.

Surface tension as an explanation for the very high strength of small fibers may be completely discounted. Griffith found the surface tension of his glass extrapolated to room temperature to be 0.0031 lbs./sq. in. The effect of surface tension on a fiber of 0.00015" diameter would account for a strength of 41 lbs./sq. in.

When the methods of manufacture of fibers and bottles are compared, two radical differences are apparent. The fiber is cooled from the high temperature liquid state to below the annealing temperature in a fraction of a second, whereas the bottle requires a very much longer time, and is held in the region of the annealing temperature for a more or less extended period. While rapidly cooled glass, especially if not annealed, shows comparatively greater strength than slowly cooled glass, there are no experiments known to the author which indicate that this method will produce anywhere near the order of strength found in small fibers.

[14]Griffith, *op. cit.* pp. 163-198.

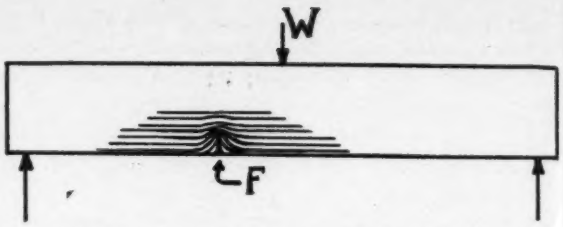


Fig. 10. Stress concentration around the apex of a flaw caused by bending stresses.

The second important difference is the stretching which has taken place. The fiber has been changed from a liquid body of molten glass by an extremely rapid drawing-out in the direction of its length into a long fiber of very small diameter. The bottle starts as a gob of molten glass and is slowly enlarged in two directions. Any inhomogeneity or aggregation of molecules in the fiber will be oriented lengthwise of the axis, whereas very little orientation will exist in the case of the bottle. This effect can be easily observed in glass which contains a few small bubbles. In rods, tubing and fibers, these bubbles are very long and small in diameter. In bottles they are usually round or slightly elliptical, with the longer axis lengthwise to the bottle. Radially they are normally rather thin. The orientation which has taken place is small and of such a nature as to increase the axial strength rather than the circumferential strength.

The bubbles in the rods of Run G had been elongated to many times their original diameter, and defects could therefore have undergone considerable orientation.

The effect of orientation has been very carefully studied in the case of rayon and other cellulose fibers. Viscose (cellulose hydrate) oriented by drawing out, has a strength of 81 kg./sq. mm., whereas unoriented fibers show only 25 kg./sq. mm. Acetate fibers orientated and not orientated give strengths of 53 and 16 respectively. If the natural silk is dissolved and then reformed into fibers the strength can be changed from 0.3 to 40 kg./sq. mm.[15] Metal wires show a like effect. That glass may contain molecular aggregates capable of orientation is indicated by R. S. Krishman.[16]

It will require more careful study to prove or disprove the possibility that orientation is the cause of the high strength of fibers. However, Berger's[17] hypothesis that the primary bonds cause polymerization during the cooling of molten glass implies a structure capable of orientation through a process of stretching.

A. A. Griffith definitely suggests orientation as the explanation for the abnormally great strength of very fine glass fibers.

Orientation, if proven, would, of course, be a factor entirely distinct from the distribution of flaws and would limit the direct use of an "Area Function" to specimens which had undergone similar treatment during the manufacturing process.

In concluding this chapter, the author wishes to emphasize the necessity of recording the size of the test pieces and the details of the method of testing. It is

[15]Houwink, R., *Elasticity, Plasticity and Structure of Matter*, Cambridge Press (1937), pp. 242, 254.

[16]Krishman, R. S., "Scattering of Light in Optical Glass," Indian Acad. Sci. Proc., 3A, pp. 211-20, March 1936.

[17]Berger, E., Koll. Beihefte, 36, 1 (1932).

hoped that the discussion of various factors affecting the test value of tensile strength measurements on glass has helped to clarify the baffling differences in the values obtained. It is believed that a useful conception of the strength of glass has been described, and, while many examples have been worked out for the purpose of illustrating the method and its application, it is hoped that too much reliance will not be placed upon the numerical values obtained.

II: TRANSPOSITION OF THE STRENGTH LEVEL CAUSED BY FLAWS

Consider the loaded test piece, Fig. 10. The load W will be supported by the bending moment set up in the test piece. There will be lines of tension parallel to and along the lower surface, and corresponding lines of compression along the upper surface. If the specimen contains a flaw (minute crack) at F the lines of tension are broken. They are forced to pass around the apex of the flaw as shown by the fine black lines. This phenomenon is known as stress concentration, and theory demands that the stresses at the apex of the flaw in a non-plastic material will approach infinity as the width of the crack approaches zero. Hence a very small crack or other molecular discontinuity may greatly magnify the value of the applied stress.[18] Generally the flaw which caused failure cannot be found in a test piece before breakage, and consequently the stresses caused by it cannot be studied directly. Nevertheless, it is these concentrated stresses which control the breakage, and which must be considered when testing glassware.

If the flaws are looked upon as being simple stress magnifiers, then the condition at the apex of the flaws will bear a simple ratio to the computed stresses in the test piece, and a number of useful conclusions can be drawn. Let

S_a = breaking strength at apex of flaw

Q_a = rate of stress increase at apex of flaw

S_o = measured strength found experimentally

Q_o = corresponding rate of application of stress

F_o = stress concentration factor of flaw responsible for S_o.

Let the same letters followed by a sub 1 have the same meaning for any other specimen. Then

$$S_oF_o = S_a$$
$$Q_oF_o = Q_a$$

In like manner:

$$S_1F_1 = S_{a1}$$
$$Q_1F_1 = Q_{a1}$$

When the conditions at the apex are the same,

$$S_a = S_{a1} \text{ and } Q_a = Q_{a1}$$
$$\therefore S_oF_o = S_1F_1 \text{ and } Q_oF_o = Q_1F_1$$

hence,

$$S_1 = S_o\frac{F_o}{F_1}$$
$$Q_1 = Q_o\frac{F_o}{F_1}$$

This means that every point in a curve showing the relation between measured breaking strength and applied rate of stress may be shifted to a new strength level by multiplying both the breaking strength and the rate of stress by the ratio of the stress concentration factors. In other words, if we have found the relation between strength and rate of applied stress, as did Black,[19] and if we change the character of the flaws so that they exert a different magnifying action upon the

[18]See Griffith (1) and Coker & Filon (8).

[19]Black, L. V., "Effect of Rate of Loading on the Breaking Strength of Glass," *Bul. Am. Cer. Soc.*, Vol. XV, No. 8, August 1936, p. 274.

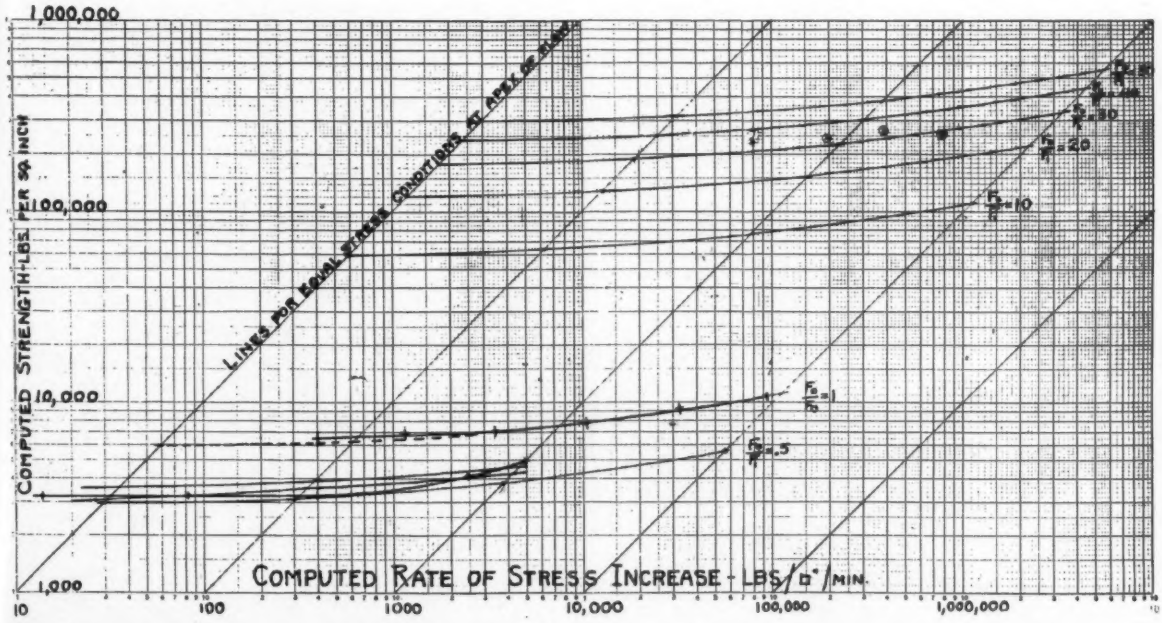


Fig. 11. Variation of theoretical strength with rate of stressing when the relative weakening effect of the flaws is changed.

stresses as might be done by acid polishing, then the new curve will be raised to a higher strength level and points on the new curve will be comparable to points on the old curve, only when the rate of loading of the specimen has been increased in the same ratio that the strength has increased.

This is more readily understood by reference to Fig. 11, which shows the computed breaking stress as ordinates and the rate of increase of stress as the abscissa plotted on log-log paper. Black's curve is used as a standard, and is marked

$$\frac{F_o}{F_o} = 1$$

The left hand end appears to be high by comparison with certain other data which will be discussed later, and it has been modified according to the dotted line.

If the flaws in the new test piece concentrated the stresses only half as much as those in Black's specimens, ($F_1 = 0.5\,F_o$), the ratio F_o/F_1 would be equal to two (2). We would have to test the acid polished piece at twice the rate of stress increase, and it would then be found that the strength would be twice as great. Such points lie on lines slanting upward to the right at 45°. This knowledge makes it an easy matter to shift Black's curve to any desired level of strength and then to show how the strength will vary with the rate of stressing. For purposes of illustration, Black's curve has been shifted to a number of new strength levels.

When a series of tests is made, the breaking strength cannot be predicted in advance. However, the rate of application of stress can be controlled. The best that can be done is to test a sufficient number of specimens using a constant rate of stress so that a reliable average can be obtained. An arithmetical average, however, is not the true average, since the relation between strength and rate of stress is not a constant. In the usual procedure, $Q_o = Q_1$ and S_1 and F_1 will have different values for each test piece. The measured strength, therefore, is always obtained at a different rate of stressing at the apex of the flaw.

Let the line "Strength vs. Rate for F_o" (Fig. 12) be the relation of strength to rate of stressing such that S_o is the breaking strength when the rate is Q_o. Then Q_oF_o = the rate of stress at the apex of the flaw resulting in the strength S_o. If we test another specimen at the same rate, and it breaks at S_1, then it must have a different (smaller) stress concentration factor (F_1). The stress at the apex of the flaw in this case will be S_1F_1. This can be compared to the strength values on the stress-rate line only, at some place where the rate of stress at the apex of the flaws will be increasing at the same rate in both cases. Let this point be S_{ax}; then

$$S_{ax} = S_1F_1 \text{ and } S_{ax} = S_{ox}F_o$$

$$\therefore S_1F_1 = S_{ox}F_{ox} \text{ or } \frac{S_{ox}}{S_1} = \frac{F_1}{F_o}$$

Let Q_x be the applied rate of stress which corresponds to S_{ox}. Then Q_xF_o = rate at apex of flaw and $Q_xF_o = Q_oF_1$

$$\therefore \frac{Q_x}{Q_o} = \frac{F_1}{F_o}$$

Hence

$$\frac{Q_x}{Q_o} = \frac{S_{ox}}{S_1}$$

It is assumed that the line "Strength vs. Rate for F_o" has been found by averaging a number of tests conducted on the same size of specimens as did Black. Each group of tests was made at one rate of stress $Q = Q_o$, and a certain number of strengths such as S_1——S_8 were obtained. If we apply the last formula to a series of rates and get the corresponding S_{ox} values, the curve xx may be drawn. Horizontal lines such as S_8 will intersect this curve at a series of points such as A_8, thus giving Q_{x8}, and this vertical line will intersect Black's curve at S_{ox8}. The point S_{ox8} is the only point on Black's curve where the rate of stress at the apex of the flaw for F_o is the same as that at the apex of the flaw F_8 which gave the strength S_8 and the rate ratio corresponding to Q_{x8}. The true aver-

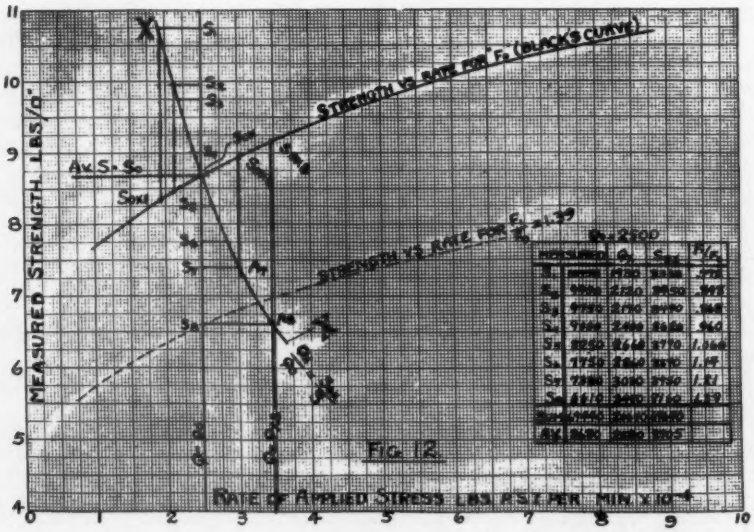


Fig. 12.

age stress is therefore the average of the values S_{ox_1}—— S_{ox_8} and the true comparative rate is the average of the various values of Q_{x_1} to Q_{x_8}. This has the effect of shifting the curve to the right by a very small amount, as shown in the table. The values of S were assumed and were given solely for illustration. Values of S_{ox} were measured from the graph, and values of Q_x were computed on the slide rule. The shift in Black's curve due to the spread of measurements is usually so small that it can be neglected.

Since the breaking strength divided by the rate is the time, all of the curves of Fig. 11 may be replotted so that the abscissas represent breaking time instead of rate of stressing, provided, of course, that the load was applied uniformly from zero to the breaking point. In some cases this method of plotting has distinct advantage, especially for very high rates of stressing such as semi-impact tests.

Summary

By considering flaws as stress magnifiers, it has been shown that:

Strength characteristics measured at one level of strength may be predicted at any other level of strength.

The strength at one rate of stressing cannot be measured because the flaws change the effective rate of stressing in a non-predictable manner.

If the relation of strength vs. rate of stressing is known at one strength level, it is possible to determine the equivalent rate of stressing and the ratio of the weakening effect of the flaws at any new level of strength from the known rate of application of stress and the breaking strength of the new test pieces.

Note: The theory applies only to glass specimens substantially free from initial compressive forces due to lack of annealing.

(*To be continued in March*)

THE MONOPOLY HEARINGS

(*Continued from page* 57)

necessary, because these "blocking patents" are usually minor affairs anyway, but also because, as Mr. McAlister of Pittsburgh pointed out, they are usually taken out when two or more powerful organizations, such as Westinghouse and General Electric, are fighting to develop a new industrial field, like turbines, according to their own notions, and the final result is development anyway, and social progress. And we would add that the normal fate of blocking patents in such a case is a "trade" of these prisoners of war between the two sides. Thus it seems clear that Owens and Hartford at one time tried to block each other, and that finally they agreed on a sort of trade, or "cross-licensing," whereby both the section machine and the feeder machines were completely "unblocked" and both did in fact reach a stage of high industrial perfection.

How remarkable that development has been was brought out in part by questions from members of the Committee to Mr. Levis and Mr. McNash. The Department of Justice itself, which had the burden of presenting the picture to the Committee, did not seem overanxious to illuminate these points. It was, however, brought out that the production of bottles had increased enormously, and somewhat steadily, for a whole generation, and that bottle prices had been falling steadily in that time, so that they were now lower than they ever had been. This had occurred in spite of very great increases in labor costs per hour. It had not resulted, either, in the displacement of labor, for the labor force was in 1937 at an all-time peak. (It is known, of course, in the industry that the labor cost per *bottle* has been increasing in recent years, though the selling price of the bottle has been going steadily down.)

It was also testified by Mr. Parham, of Hartford, that the effect of the Hartford licensing policy had been to keep in business a large number of small concerns which would probably have collapsed if the Feeder patents had been used to put Hartford in the glass manufacturing business. There are at the present time 45 firms in the country making glass containers, and it is known that on the average the small companies have been increasing their share of the business, and while the large companies have been growing, the little ones have been growing faster.

It was also testified that the composition of the industry has not been fossilized. In recent years 20 or more new companies have entered the field. A somewhat comparable number have gone out of the business. It follows that the industry does not lack new blood, and that it is anything but static.

The vastly increased efficiency of recent years has produced some curious results. For instance, while the volume of bottles increases continually, and the labor force is at an all-time peak, and payrolls likewise, yet the industry still has a vast overcapacity: it cannot use anything like all its tanks at full power, for the efficiency has gone up and more can be produced from each tank. In consequence, there is a general feeling throughout the industry that new entrants into the field should not at present be encouraged. This agrees with a remark made by the president of a progressive smaller company, a few years back, to the present writer: "I want another plant, but there is no sense in building a new plant; and if I buy another company, what I am interested in buying is not their plant, but their business, that is, their clientele." The chronic over-capacity of a rapidly expanding industry is surely a rather unusual phenomenon.

Mention was also made at the hearing that this industry, more than any other probably, has maintained steady employment throughout the depression. Taken by and large, those men were fortunate in the last decade who found themselves employees of the glass container industry. This may have been partly sheer good luck, or partly good management; but in any case it can confidently be said that the social security and stability offered by this industry has been in marked contrast with the wild disorder of the automobile industry. It was Michigan that precipitated the financial debacle of 1931 and 1932, and it was the automobile industry that was Michigan. And it was the collapse of the automobile industry that produced the unemployment in the plate glass field.

In spite of all this, the writer got the impression that the Department of Justice had been going out of its

(*Continued on page* 68)

R. L. Warren takes it easy after a day in the woods. Bob has taught son George to become a first-class marksman.

The odds are not all with the hunter—sometimes he too gets partly shot.

HUNTING TIME AT BROCKWAY

Scene: Whetstone Run Cottage, the hunting lodge of Mr. R. L. Warren, president of the Brockway Glass Company. *Dramatis Personae:* Glassmen and glass packers—those seen here being but a few among scores in many parts of the United States who have known the hospitality of this place.

The time is deer hunting season; or, more specifically, early December. Trains and motor cars unload and carry away a constant stream of Mr. Warren's personal and business friends; some coming to hunt, others for the delight of comradeship. It has been said that a person may stand on the reservoir dam during hunting season and meet more glassmen than he could by a month of travel.

Life at Whetstone Run Cottage is the life of the woods—of the forest trail, with heads bent to the wind and the sting of snow. It is the life of the hunt, where pride of achievement is honored less than good sportsmanship; where the trail ends at a roaring log fire—the brimming glass, the tale well told, the carefree laugh.

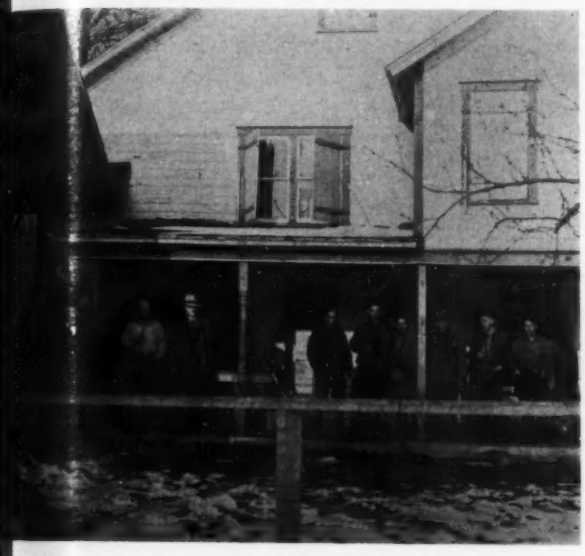
Every camp has its important character and Whetstone Run Cottage has a famous one indeed—chef John Nava. His mother wanted him to become a pastry chef, and taught him to cook as few men can. But John Nava had other ideas: He opened a machine shop and sharpened the tools used in building the water company; he helped construct the reservoir down by the side of which Whetstone Run Cottage is located. Three of his sons are glassmen.

All of this, as we have said, is the realm of Mr. R. L. Warren, president of the Brockway Glass Company Mr. Warren is also president of other local enterprises—the water company, with its 8,000 acres of forest land; and a most interesting and (finally) profitable mink and silver-fox farm. "Bob" is one of Brockway's leading citizens—not because he is the motivating force behind so many of its important enterprises, but because he loves his community and his heart and soul are with it.

Glassman should know better than to try to match wits with a distiller—in any kind of a deal he's apt to hold all the aces.

Typical of the country surrounding the hunting lodge. The soil was never sufficiently fertile for agriculture, even in Indian days. Good coal and clay deposits abound. The first growth pine and hemlock was cut over years ago when this was a great lumber region.

This fawn must have got in the way of the gun—he looks too small to have been deliberately hit.



Nimrods on the porch of Whetstone Run Cottage.

John Nava, chef *par excellence.* New York City's leading hotels have tried unsuccessfully to lure him from the Pennsylvania mountains.

There's nothing like a day's tramp through the snow covered mountains to stimulate appetites. Incidentally, it's the one event of the day that brings the whole camp together. Note the bow and arrows on the wall—steel tipped, of razor-like sharpness and meant for business. One of the hunters uses these weapons from preference.

THE MONOPOLY HEARINGS

(*Continued from page* 65)

way to pat the automobile industry on the back, and to kick the glass container industry in the pants. If social insecurity is what the Department wants, they are going the right way to get it. We believe, on the contrary, that the glass container industry has contributed greatly to social stability in the last decade, and that this has been partly due to the steadying influence of the two organizations, Owens and Hartford, which the Department was doing its best to impeach.

PATENT HEAD WANTS TIGHTER MONOPOLIES

Defense of the patent monopoly system as essential to the well-being of the national economy was undertaken by Conway P. Coe, Commissioner of Patents, before the Senate investigating committee which resumed its hearings on January 16, following a month's holiday recess.

"What we need is not to decrease but to enhance the monopoly called a patent," he testified. "Genuine protection in that form would be the last surviving bulwark standing between the inventor and the onslaught of mighty and ruthless corporations."

Asserting that the new inventions could be made of value to the nation only by their exploitation, he continued:

"Speculative capital must be encouraged to fall in behind a new industrial enterprise, and this is true whether the enterprise is wholly new or represents merely an expansion of an established organization. . . . In the long run, new processes and new products offer our greatest hope for a progressive rise in the standard of living and for increased opportunities of leisure time."

Conceding that defects in the present laws existed, Mr. Coe recommended seven major changes. These were:

A twenty-year limitation on the combined period in which patent applications may be pending and the patent monopoly may run, without increasing the monopoly beyond the present statutory period of seventeen years. The present laws permit the application to be pending and the patent to run for a total of forty-four years.

A single court of patent appeals so that appeals from decisions of Federal district courts can be taken to only one appellate court.

Elimination of several present steps in interference procedure by making the initial ruling of the examiner of interferences final for the patent office and any appeal direct to a Federal court.

Reduction from two years to one year of the period for copying a claim from an issued patent to assert prority of invention.

Extension of the commissioner's authority to require an applicant to respond to an office action within less than the normal statutory period of six months, with a possible restriction to within not less than thirty days.

Abolition of renewal applications, with the proviso that the Commissioner, upon proper showing, have authority to receive payment of the final fee after the statutory period for payment, thus protecting poor inventors who might lose their rights for lack of fee.

Reduction of the period in which an inventor may have public use of his invention prior to filing his application from the present two years to one year.

Resumption of the anti-monopoly hearings marks a new phase in the investigation. Prior to the holiday recess, they had considered the patent laws only from the viewpoint of the Department of Justice, which had endeavored to show that the anti-trust laws were being circumvented by patents. During the January hearings, the Department of Commerce will try to develop how the patent laws are essential to industrial and economic progress.

Current gossip in the Capitol indicates that Congress is hostile to Thurman Arnold and that the milder viewpoint has a good chance of prevailing.

PENN STATE AND VIRGINIA POLYTECHNIC CERAMIC DEPARTMENTS ACCREDITED

The 1938 report, just released, of the Engineer's Council for Professional Development, carries the announcement that official accrediting has been extended to the ceramic engineering departments at Penn State and at Virginia Polytechnic Institute. The complete list of accredited ceramic departments has now been raised to eight. The six departments previously accredited were the University of Illinois (Technical Option), Missouri School of Mines & Metallurgy, New York State College of Ceramics, Ohio State University, North Carolina State College and the University of Washington.

The E.C.P.D. report shows that eleven ceramic departments were examined by their committees. Of the eight departments accredited, only six were given "unprovisional" approval. In general a provisional approval indicates that continued accrediting is dependent upon improvement in teaching staff or curricula.

The E.C.P.D. examines schools for accrediting only upon invitation of the school itself.

Accrediting of engineering departments is of value for a number of reasons. It improves engineering curricula by providing a measuring stick so that the department heads will know whether they are maintaining standards commensurate with those of other schools. E.C.P.D. accrediting has also in a broad way been recognized by the various state boards of engineering examiners and by technical engineering societies in evaluating the training of engineering graduates.

In its recent accrediting of ceramic departments the E.C.P.D. has been assisted by representatives of the American Institute of Ceramic Engineers.

The latest annual list of E.C.P.D. accredited engineering departments may be obtained from the Committee's headquarters at 29 West 39th Street, New York, N. Y.

COURSE IN TECHNICAL WRITING

Needs of the worker in a specialized field for proper organization of his material and an approved writing style to meet the requirements of trade and technical publications are answered in a home-study course, "Composition of Technical Papers," offered by the Extension Division of the University of Wisconsin, Madison. The course is given as a helpful means of acquiring excellence in writing under guidance, without interruption to the daily occupation, and is available to individuals in any state.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_710H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 - .0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0865	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	28.00	....
In bags	ton	29.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0725	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	11.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	10.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	13.00-14.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.029	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.07
Antimony oxide (Sb_2O_3)	lb.	.11½	.12¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.04-.04¼	.04½-.05
Tin Oxide (SnO_2) in bbls	lb.	....	.50
Titanium Oxide (ceramic grade)			
In bags	lb.	.12¼	.12½-.13
In barrels	lb.	.12½	.12¾-.13¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .02¼-.02½ higher)		.024	.029

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	.80-.85
Chromite (99% through 200 mesh)	lb.	35.50	40.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.165
Black (CuO)	lb.	....	.16-.17
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	47.50	50.50-54.50
In Burlap bags	ton	49.25	52.25-57.25
In Casks	ton	51.50	54.50-59.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09¼-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.2075-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08¾-.08¾
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65.
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¾
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

THE SUDETENLAND ANNEXATION

(*Continued from page* 58)

Production of window glass in 1937 was between 13 and 15 million square meters, almost half of the total German production thereof which amounted to 30 million square meters. But since the domestic requirements were small Czechoslovakia was able to export 10 million square meters or about double that of Germany.

Since 1928 the sales of the entire production of the strictly organized plate glass industry of Czechoslovakia have been regulated by the Verkaufsgemeinschaft Böhmischer Tafelglasfabriken A.G. (Bohemian Plate Glass Factories' Sales Society). The Czechoslovak combine acquired the majority stock of a Hungarian glass factory in 1930 and in the following year constructed a mechanically operated window glass factory in Yugoslavia. In 1932 sales in Germany were entrusted to the Vereinigte Deutsche Glashütten (Union of German Glass Factories).

The improvement in the machine production of window glass and especially in thick glass produced in the Sudeten District has considerably influenced the development of mirror glass production. The two sole Czechoslovak mirror glass plants were merged last year into a company called Myrolitte A.G. in which the St. Gobain concern is interested. The incorporation of the Myrolitte A.G. in the glass industry of greater Germany will occasion no difficulties since that concern with a quota of about four per cent is already a member of the International Mirror Glass Syndicate. The Myrolitte concern also produces "Sekurit" (safety) glass.

German factories have had considerable interest in the third branch of the plate glass industry, i.e., cast glass for wire and ornamental glass for technical purposes. The Tafel- und Farbglaswerke G.m.b.H. Zuckmantel belongs to the domain of the Jenaer Glaswerke Schott u. Gen., Jena; The Gussglasfabrik Neusattel to Siemens Glass and the Glasfabrik Bilin, Engels & Co., K.G. is considered as belonging to St. Gobain.

By the acquisition of the Sudeten glass factories the production capacity of the glass industry of Greater Germany will be increased by approximately one-third and that country thereby may become the leading producer on the continent.

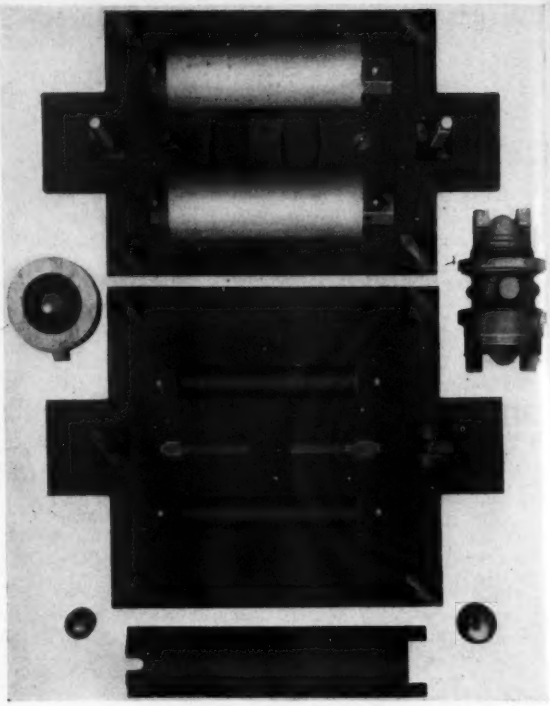
The Achema IX, Chemical Engineering Show, organized by the Dechema, German Society for Chemical Engineering, will be held at Frankfort A/M, June 28-July 7, 1940.

FOR SALE **FOR SALE**

Dismantling New Eagle plant of American Window Glass Co.

3—Camden Iron Works heavy duty gas producers
2—Ladd water tube boilers 215-hp 150# pressure
2—150 kw 250 v DC Westinghouse steam generators
140—30" gauge glass buggies with roller bearings

HETZ CONSTRUCTION CO., INC.
WARREN, OHIO NEW EAGLE, PA.



Metal patterns for accuracy, fast delivery and production economy

BY STOCKING metal patterns for diversified glass house castings, Gunite Foundries is able to offer important economies, prompt delivery and castings of highest fidelity to specifications. But in addition to superior service, consider the inherent properties of GUNITE:

For one thing, GUNITE has four or five times the operating life of ordinary glass mould iron—an important economy for you. Because it has just the right hardness and polish to produce lustruous, smooth ware singularly free from defects, it will help to increase the sale of your product and give you greater profits.

Our fifteen years of research and five years of testing under actual operating conditions is suggestive of GUNITE's great value to the glass industry and of its ability to contribute the answer to your mould problems.

Send for the booklet describing the complete line of GUNITE castings—round bar stock, Miller plungers and guide rings, neck ring sticks, bushing stock, press and blow moulds, and metal patterns.

GUNITE FOUNDRIES CORPORATION
ROCKFORD ILLINOIS
Established 1854

ISCO CHEMICALS

ISCO
CARBONATE
OF POTASH

Dustless Calcined 98/100%
Hydrated 83/85%

ISCO
CAUSTIC POTASH

Granular 90/92%

Special Glassmakers Grades made at our Isco Division, Niagara Falls, N. Y.

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DESIGNS
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Quality and Quick Service
....350 EMPLOYEES
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CLEVELAND TRAMRAIL
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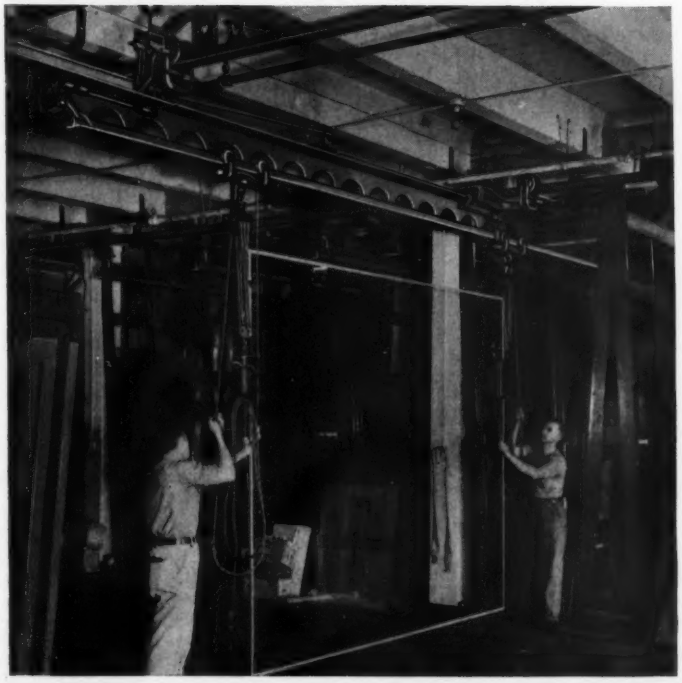

● Cleveland Tramrail, in addition to serving the Glass Industry for accumulation and conveying to the mixers and from the mixers to the furnace, is useful for

Product handling

Through certain other phases of production

For storage
For shipping

Consult your phone directory under Cleveland Tramrail.

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THE CLEVELAND CRANE & ENGINEERING CO.
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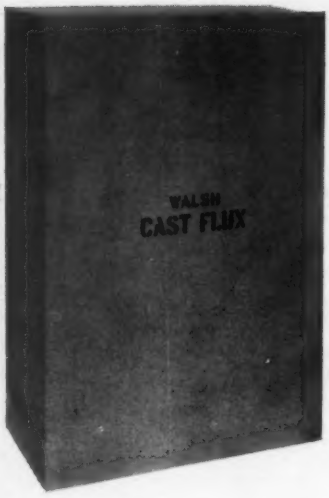
WALSH CAST-FLUX



The Vacuum-cast flux block of superior quality.

Walsh Cast-Flux blocks are machine-trued to exact size and shape after burning.

THEY LAST LONGER

The excellent results obtained in numerous tanks melting various types of glass has definitely established the efficiency and economy of Walsh Cast-Flux blocks.

Walsh Cast-Flux has a dense, uniform structure; it is burned at higher temperatures, is thoroughly bonded and possesses a low coefficient of expansion.

Walsh Cast-Flux blocks meet the most rigid requirements for tanks operating at higher temperatures . . . they insure greater tonnage, higher quality glass, freedom from defects, longer life and maximum economy.

WALSH REFRACTORIES CORPORATION

Manufacturers of Refractories for the glass industry for over 50 years

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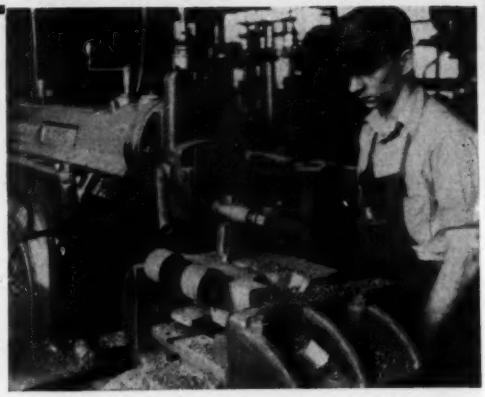
St. Louis Missouri



Machining the face of a section for a bottle mould.

• **The production of moulds for glass manufacturing is a task in which high grade workmanship is combined with first-class equipment.**

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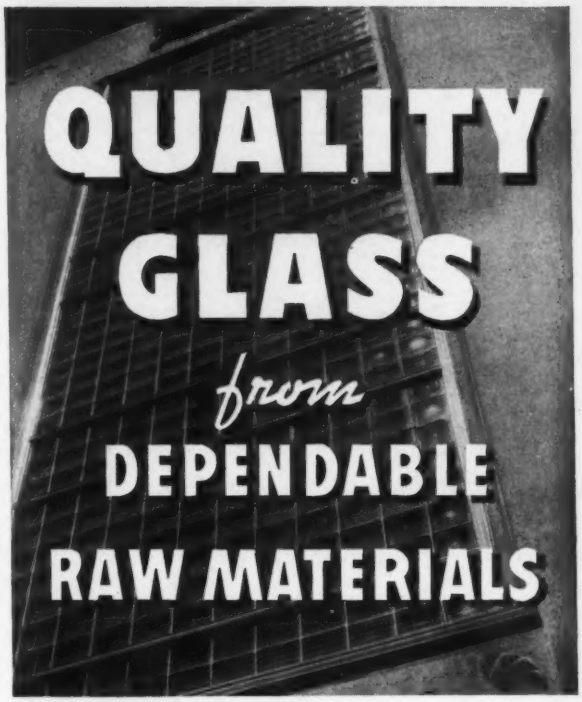

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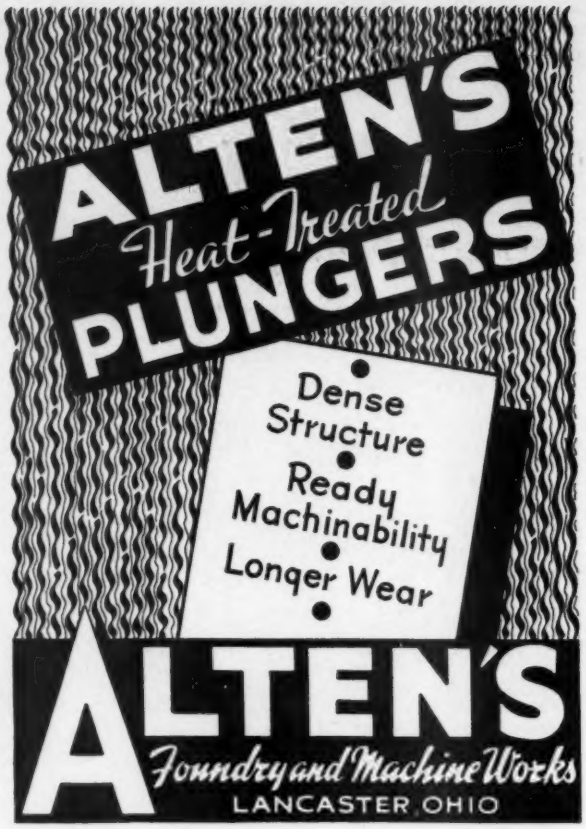

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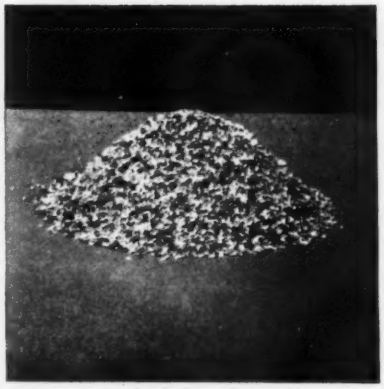

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